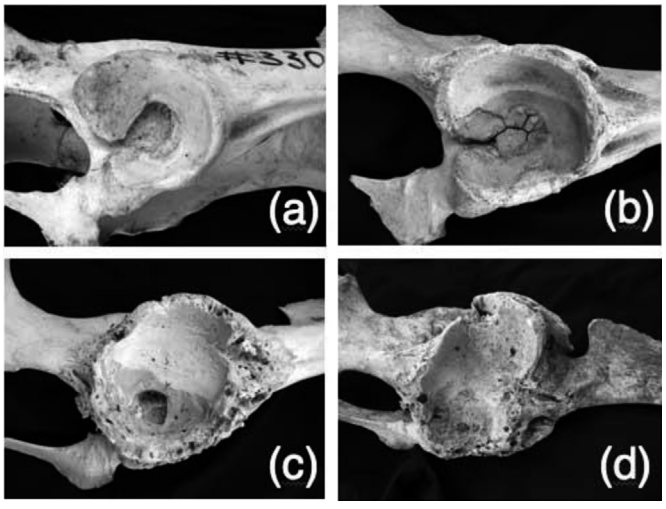
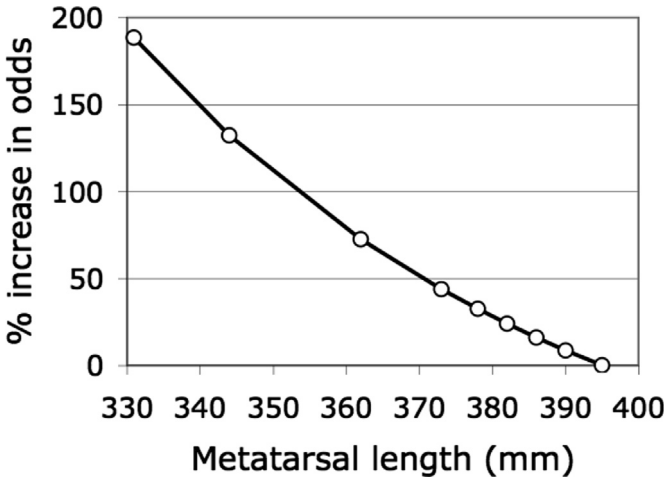
short metatarsus length, is correlated with higher prevalence of OA among moose that survive to at least nine years of age. Hip OA is four times more prevalent in old males than old females. We sought to evaluate structural integrity of femurs from high-risk (HR) and low-risk (LR) males at a young age, distinguished only by metatarsus length. We also tested the hypothesis that biomechanical loading differences arising from pelvis shape might explain the gender difference in OA risk.

Methods: Complete dry skeletons from 541 moose that died in a catastrophe (starvation due to an exceptionally severe winter) were evaluated for presence or absence of hip OA based on osteophytes and modification of the joint surface in the acetabulum. The sex of each moose was determined from skull morphology (presence of antlers) and age was estimated from counts of cementum annuli in teeth. Femurs from four young adult males each in HR and LR groups (metatarsus length in low 25th percentile and high 25th percentile, respectively, but without OA) were assessed for bone structural integrity using reference point indentation (BiodentTM, Active Life Sciences). For micron-scale indentation tests, a reference force of ~13N was applied to the medial surface of the diaphysis of the femur. Indentations were taken at 5 locations along the medial line (midpoint +/- 10mm and 20mm proximal and distal). The indentation test included a series of 20cycles at 2Hz to a force of 10N. For each group of moose, we calculated the average response with respect to total indentation depth increase (IDI), first cycle unloading slope, first cycle energy dissipation, first indentation distance, and total energy dissipation. For this moose population, we characterized the differences between sexes with respect to pelvis morphology on the basis of three angular measurements from the ishiatic arch, lesser sciatic notch, and pelvic brim.

Results: OA was identified in 107 (20%) of moose examined. There were no significant differences in diaphyseal cortical bone material properties of the femur between HR and LR groups. Pelvis morphology differed ($P<0.001$) by gender; for angular measurements, the ratio of female/male was 1.59 for ishiatic arch, 1.06 for lesser sciatic notch, and 0.90 for pelvic brim. The resulting gender difference suggest that females exhibited a more splayed-out lateral orientation of the acetabulum, which likely provides increased femoral head coverage and support for acetabular loading from the femur.

Conclusions: OA is a debilitating disease for moose that are preyed upon by wolves. A higher prevalence of hip OA in males correlates with a shorter average life span in males. This study suggests that acetabular joint loading differs by gender, with reduced acetabular coverage of the femoral head in males, resulting in more dorsal acetabular rim loading compared to female moose. Males also exhibit accelerated skeletal growth, greater tooth wear, and greater prevalence of osteoporosis and periodontal disease compared to females. A limited evaluation of cortical bone material properties did not reveal differences between HR and LR groups in young moose, even with evidence of early nutritional differences that are correlated with late-onset OA.





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MEDIALIZING FOOT CENTER OF PRESSURE WITH FLEXIBLE SHOES IS ASSOCIATED WITH A MEDIAL KNEE LOAD REDUCTION IN KNEE OSTEOARTHRITIS

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Purpose: Biomechanical treatments for individuals with medial compartment knee osteoarthritis (OA) often target the knee adduction moment (KAM). Foot-mediated biomechanical interventions for knee OA may operate through altering the foot center of pressure (COP). Flexible footwear has recently been shown to be effective at reducing the KAM, but the specific mechanisms underlying this reduction are not clear. The primary aim of this study is to determine if the reductions in KAM through use of flexible footwear are associated with a shift in foot COP. We hypothesize that by increasing foot mobility and foot pronation, flexible footwear may promote a medial shift in foot COP that is associated with reduction in the KAM.

Methods: Participants with symptomatic medial compartment knee OA (KL 2 and 3) and KAM greater than 2.2 %BW*Ht in their own shoes during gait analyses were evaluated. 3-D gait analysis and foot COP analysis was performed at baseline. All participants were provided flexible shoes (Dr. Comfort Flex-OA, Mequon, WI) and instructed to wear them at least 6 hours/day, 6 days/week. Gait analyses and COP analyses, were repeated after 12 weeks of wearing the shoes. The gait test consisted of five barefoot walking trials, five walking trials in subjects "own shoe", and five walking trials in the flexible shoe. During barefoot trials only, plantar pressure distribution was acquired simultaneously by mounting a pressure platform (Emed, Novel, Munich, Germany) onto a force plate (Bertec, Columbus, OH) and leveling the stacked assembly with the walkway. COP was quantified by determining the Medial to Lateral Pressure Index (MLPI) (Fig.1), with more negative values representing more medialized COP. The primary outcomes of interest for this analysis were the peak KAM and COP during the first half of stance. Paired samples t-tests were used to compare subjects' shifts in COP between baseline and 12 week visits and to compare changes in KAM in their own shoe at baseline and in the flexible shoe at 12 weeks. Spearman correlations were used to evaluate the association between the shift in COP and percent reduction in the KAM. Independent samples t-test was used to evaluate changes in COP between knee unloading responders vs non-responders.

Results: Fourteen participants were evaluated (mean age 59±6 yrs, 9 women, mean BMI 28±4 kg/m2). At 12 weeks, the KAM during the first half of stance in the flexible shoe was reduced by 8% compared to in their own shoes at baseline (2.55±0.63 %BW*Ht vs 2.78± 0.61 %BW*Ht, $p=0.032$). The barefoot COP, as measured with MLPI, was medialized at 12 weeks (13.03±10.34mm) compared to at baseline (19.68±13.61mm)($p=0.034$). The percent reduction in KAM during the first half of stance was significantly correlated with a medial shift in COP

throughout stance (rho=0.626, p=0.017)(Fig.2) and approached statistical significance for the medial shift in COP during the first half of stance(rho=0.490, p=0.075). Subjects who responded to the flexible shoe intervention (n=11), defined as more than a 5% reduction in KAM at 12 weeks compared to their own shoes at baseline, had a greater medial shift in barefoot COP than subjects who did not respond(n=3) (p=0.008)(Fig 2).

Conclusions: Over 12 weeks of use, walking with flexible shoes significantly reduces loading at the medial tibiofemoral joint in participants with knee OA and shifts the foot COP medially during barefoot walking. This medialization in foot COP is directly associated with the reduction in dynamic medial knee loading. Understanding these relationships may help design future biomechanical interventions for knee OA as well as make recommendations regarding choice of footwear.

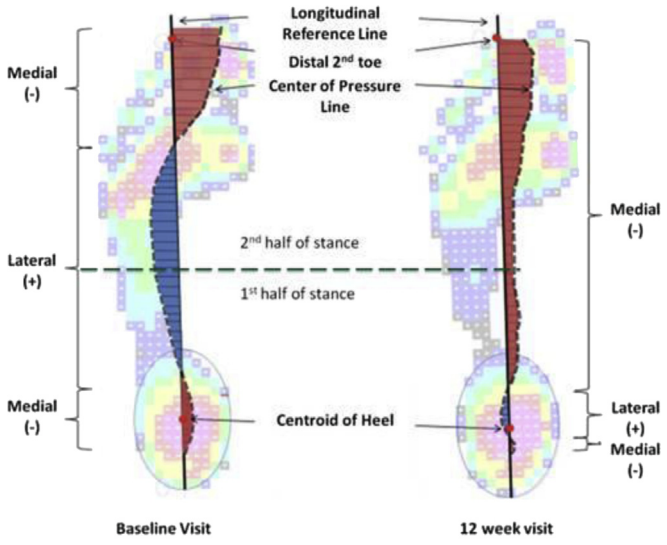

Figure 1. Medial-Lateral Pressure Index (MLPI): MLPI compares the COP line during gait to the anatomical longitudinal center line of the foot, defined as a line connecting the midpoint of the tip of the 2nd toe and the centroid of the heel.

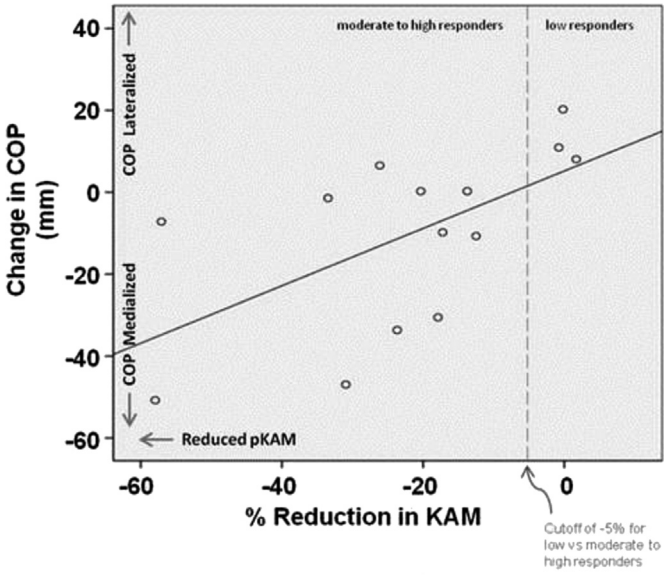

Figure 2. The relationship between the change in KAM and the shift in COP (MLPI). The larger the KAM reduction, the greater the medialization of COP.

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BIOMECHANICAL AND NEUROMUSCULAR ALTERATIONS IN KNEE OSTEOARTHRITIS AND ASYMPTOMATIC CONTROLS: A LONGITUDINAL STUDY

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Purpose: Cross sectional studies report differences in knee joint biomechanics and muscle activation patterns during gait among those with different medial compartment knee osteoarthritis (OA) severity and asymptomatic controls, providing evidence of a link between the local joint loading environment and OA progression. Due to a lack of longitudinal data, the effect of time on these patterns and whether those with knee OA experience more rapid changes is unclear. This study sought to determine whether knee joint moment and muscle activation pattern alterations during gait at follow-up were different between those diagnosed with mild/moderate knee OA and asymptomatic controls (ASYM).

Methods: Seventy nine participants 35 years or older (ASYM, n=41 and OA, n=38) had three dimensional lower limb motion, ground reaction forces and surface electromyograms (EMG) from medial and lateral vasti (VM/VL) and hamstring (LH/MH) muscle sites recorded during self-selected speed walking at two sessions: baseline and follow-up (5+ years later). OA diagnosis was based on clinical and radiographic criteria (Kellgren Lawrence median score=2) and mild/moderate classification was based on functional and clinical criteria at baseline. Knee joint moments (flexion-KFM, adduction-KAM and internal rotation-KRM) were calculated from inverse dynamics and were amplitude-normalized to body mass (Nm/Kg). Surface EMG were normalized to maximum voluntary isometric contractions. Moment and EMG Waveforms time-normalized to gait cycle were entered into Principal Component (PC) Analysis models to capture key waveform features. Each participant's waveform was scored for each PC. Three factor (group, session, sex) ANOVA models tested for main effects and interactions for each PC score ($\alpha = 0.05$). Tukey post hoc analyses were performed on significant results.

Results: ASYM were younger (47.4±8.1 vs 56.9 ±7.2 years), had lower BMI (25.5±4.4 vs 30.8±5.8 Kg/m2) and lower WOMAC Total scores (0.2±1.0 vs 28.7±17.9) than OA at baseline. Follow-up sessions occurred 7±1.6 and 7±1.9 years after baseline for ASYM and OA respectively. Related to the study purpose, significant session and session by group interactions only are presented here. Gait speed did not change for the ASYM group (1.39m/s), but was lower at follow-up (1.17m/s) compared to baseline (1.25m/s) for the OA group. Four of 7 moment PC scores were different ($p<0.05$) between sessions: KFM showed prolonged flexion during mid-late stance, higher extension moment peak at heel strike, higher overall KAM magnitude and higher mid-stance KAM amplitude for session 2. Two moment PC scores had group by session interactions ($p<0.05$): ASYM group at session 2 had greater difference between initial peak and mid-stance KAM amplitude compared to OA for both sessions; ASYM had a larger difference between the early external and late internal KRM for session 1 compared to all others, with the late stance KRM for OA session 1 higher than both groups for session 2 (Figure). Three of 12 EMG PC scores had significant ($p<0.05$) session main effects or interactions. Overall MH activity was higher for OA session 2 compared to both ASYM sessions (Figure), but neither group had a session difference. VL had a group by session interaction with the late stance/early swing activity lower in OA session 2 than all others. VM session main effect showed higher activity in late stance/early swing for session 1 versus session 2.

Conclusions: Higher overall and mid-stance KAM magnitude and prolonged KFM during mid-late stance at session 2 are features previously associated with higher OA severity. Since they were not specific to the OA group, these features may be more sensitive to aging changes in joint structures. Only one ASYM subject developed symptomatic OA, but 14 OA participants progressed based on a one grade change in medial joint space narrowing (JSN) score, with 5 having maximal JSN at baseline. Decreased gait speed, KAM early to mid-stance magnitude, KRM range, and increased medial hamstring magnitude in the OA compared to ASYM group between sessions are also consistent with pattern alterations from cross-sectional studies of knee OA severity. Interactions indicate a differential response in these features over time with knee OA. In conclusion, specific